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Extension of FM Broadcast Range

Experimental research conducted by K. A. Norton of the National Bureau of Standards indicates that the reliable service areas of frequency-modulation (FM) broadcasting stations using transmitters now available may be extended far beyond the horizon. Analysis of the time variation of intensities received during the past year from FM stations has shown that atmospheric "ducts" and boundary layers in the lower troposphere both have the effect of reducing the attenuation of high-frequency radio waves with distance at points beyond the line of sight. These results are expected to provide a firmer basis for the prediction of the service and interference ranges of FM broadcasting stations; they should also aid in the solution of problems that may occur in connection with other uses of the spectrum above 30 megacycles.

The increasing use of frequency modulation for broadcasting is a result of such obvious advantages as the almost complete freedom from interference between stations and from static due to atmospheric or man-made disturbances. The transmission of a much greater volume range and a wider audio frequency range than is possible with amplitude modulation thus becomes feasible. However, a limitation on the distance range has been imposed by the necessity of employing very high carrier frequencies (from 88 to 108 megacycles per second). At such high frequencies long-distance propagation by means of alternate reflection of the waves from the ionosphere and the earth no longer occurs, and the range of a station has been ordinarily limited by the earth's curvature to 100 miles or less.

Variations in the density of the atmosphere within a few hundred feet of the ground provide differences of refractive index that can increase the curvature of a radio wave by an amount equal to or greater than the curvature of the earth. Known as ducts, these characteristic changes in the refractive index of the air near the surface of the earth become more and more effective in bending radio waves as frequency increases.

For the overland propagation paths that are usually involved in frequency-modulation broadcasting, effective atmospheric ducts are to be expected after the sun sets and the earth begins to cool the atmosphere. Under favorable circumstances this cooling may continue throughout the night with the formation of a duct of great width. The received fields would then be expected to reach their peak values early in the morning before the sun has had opportunity to destroy the duct by warming the earth.

This general behavior has been observed for the fields of FM broadcast station WCOD at Richmond, Virginia, as received at the National Bureau of Standards in Washington, D. C. On August 4, 1947, for example, the station began broadcasting about 6:25 in the morning. Throughout the day the fields gradually increased until a little after midnight. At this time the received field increased markedly, and the fading, which had occurred at a fairly rapid rate during the day, decreased both in amplitude and frequency of occurrence. The calculated field intensity corresponding to propagation in a vacuum over a flat earth was exceeded for the half hour just prior to 1 a. m., when the station went

off the air. Presumably this favorable propagation condition lasted throughout the night since the fields were again very strong on the following morning when the station began broadcasting at 6:25 a. m. The mechanism responsible for the strength of these fields and for the comparative absence of fading is considered to be atmospheric refraction.

One of the outstanding characteristics of FM broadcasting is the very low field intensity required for satisfactory reception. During most of the time in rural areas where weak fields are the only ones available for broadcast reception, the only interference to such reception arises from the radio noise generated in the high-frequency circuits of the receiver itself and the cosmic radio noise originating in the stars and interstellar space. Studies of such noise sources at the National Bureau of Standards indicate that received fields as low as 5 microvolts per meter provide a satisfactory grade of FM broadcast service when a very good radio receiver is employed in the absence of man-made noise or local thunderstorms; and not more than twice this value is required with typical receivers now available to consumers. Thus, the most effective way to increase the service range of an FM broadcast station is to increase the transmitting antenna height rather than the power, since such a change, by lengthening the line of sight, increases the service range more rapidly than the interference range, resulting in a more efficient utilization of the channel. An analysis of field intensity recordings made of station WCOD for the entire period between June 10 and August 8, 1947, inclusive, showed that 5 microvolts per meter was exceeded for 99.3 percent of the time. The signals from this station were observed to be of broadcast quality during most of this period, even when received in the presence of the rather high man-made noise level at the Bureau.

During the middle of the summer day or in the winter, when atmospheric ducts are less effective in bending radio waves around the earth, received fields are weaker and are usually characterized by somewhat more rapid fading. The rapid variation in intensity of the waves is attributed to reflection at nearly grazing incidence from a multiplicity of horizontal tropospheric boundary layers at heights up to 10,000 or 20,000 feet. These layers are caused by comparatively sharp gradients in

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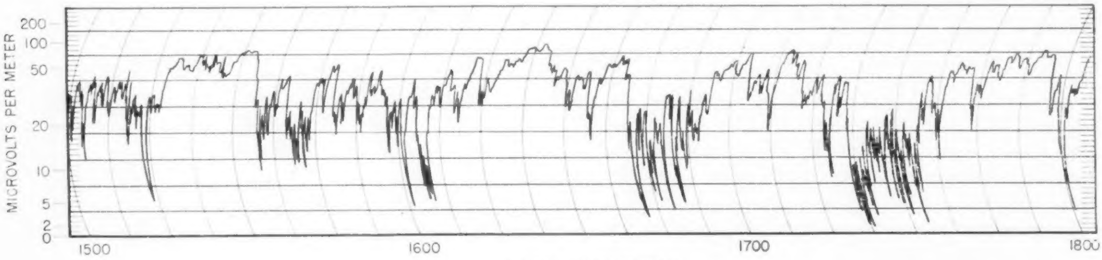
the refractive index of the atmosphere. As the total energy in the waves reflected from the atmospheric discontinuities may be comparatively constant for several hours, the observed intensity fluctuations are believed to be due simply to phase interference between wave components that have been reflected at various points in the troposphere. Under such circumstances the time variation of the instantaneous intensity of the received waves would be expected to follow the Rayleigh distribution. The intensities recorded at the Bureau fit this distribution closely, providing strong support for an explanation in terms of phase interference.

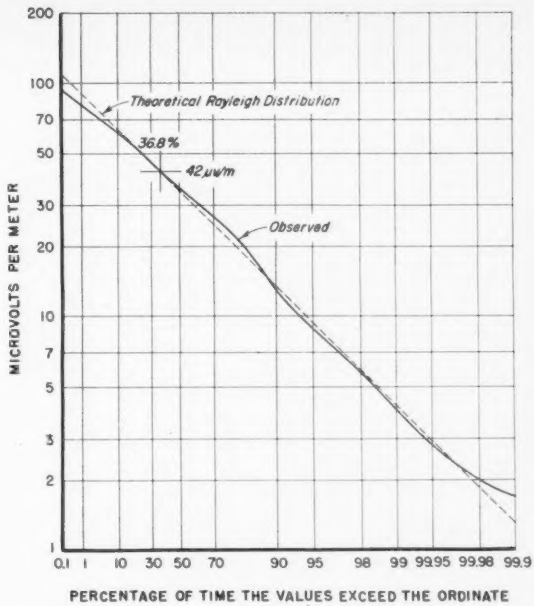
From analysis of the field-intensity data obtained by the Bureau, it appears that external receiving antennas



A 3-hour record of field intensities received at the Bureau from FM broadcast station WSAP in Portsmouth, Va., illustrates the rapid fading of the field at points far beyond the line of sight in the absence of effective bending of the waves to the earth's curvature by atmospheric refraction. This rapid fading is considered to be due to reflection at nearly grazing incidence from horizontal boundary layers in the troposphere, which are caused by sharp gradients in the refractive index of the air.

may be used with considerable advantage for reception of FM broadcasts at points far beyond the horizon of the transmitting antenna. The FM fields from stations at large distances may be expected to reach their maximum levels in the early morning hours during the summer months; at these times effective ranges up to several hundred miles may be expected.

With increasing frequency the effectiveness of atmospheric ducts becomes greater and the boundary layer reflection coefficients decrease. Since these two tendencies affect attenuation of radio waves in opposite ways, it seems probable that there exists, for a particular set of conditions in the lower troposphere, an optimum frequency for propagation to large distances beyond the horizon. However, experimental data now available are not sufficient to locate these optimum frequencies in the spectrum.



Intensities of the received waves for the 3-hour period of recording are plotted on graph paper especially designed so that data distributed in accordance with the Rayleigh distribution will be on a straight line with a slope of minus 1. The close fit of the experimental data to such a line gives strong support to the assumption that the rapid variation in received field intensities is due to phase interference of wave components reflected from horizontal boundary layers in the troposphere.

Bone Char Research

Increased understanding of the properties of commercial solid adsorbents and their basic behavior as related to structure has resulted from a long-range cooperative program of research initiated at the National Bureau of Standards in 1939 for a fundamental study of sugar refining problems. Of particular interest to sugar refiners are the results obtained for bone char. Exhaustion of the char with repeated use has been shown to be accompanied by a reduction in surface area of the granules, which are found to retain the intricate, porous structure of bone even on a submicroscopic level. Further studies aimed at improvement of the present methods for revivification of the used char are now in progress.

Bone char is a granular solid adsorbent used in great quantities for the decolorizing and purification of raw sugar. This is accomplished on a plant scale by passing the sugar liquor through one of a number of filters about 10 feet in diameter and 20 feet deep that contain the char. Approximately 9,000,000,000 pounds of raw cane sugar are refined annually in the United States, requiring the use of approximately half this weight of bone char. Actually, of course, so enormous a quantity of bone char need not be in existence at any one time, since in practice the char undergoes many repeated regenerations.

Although large-scale revivification of bone char by a process involving successive washing, drying, and heating has been employed in cane sugar refineries for about 50 years, improvements in revivification methods have not kept pace with modern trends in industrial operations. The gradual exhaustion of adsorptive properties with use and the small loss of dust formed in attrition must be compensated for by a small and steady addition of new char. Moreover, the properties of the resultant char mixture are not always predictable. An analysis of what actually occurs is thus of great practical value to the industry.

Prior to 1939, detailed basic knowledge of the bone char process in sugar refining was very meager. For a long time it had been evident that additional scientific information regarding the fundamental nature of commercial solid adsorbents was necessary for further improvement in sugar refining technology as well as in other applications. A research program for such a study was initiated at that time by Frederick J. Bates of the National Bureau of Standards. Interest in the project,[1] now under the direction of Dr. Victor R. Deitz of the Bureau's surface chemistry laboratory, has steadily increased until today industrial supporters of the work include almost all of the cane sugar refiners and bone char manufacturers of the United States, as well as those in Canada, England, Australia, and South Africa. Close cooperation between the Bureau and the sponsors is attained through the Bone Char Research Advisory Committee composed of members of the industry and a staff member of the Bureau, under the present chairmanship of J. M. Brown.

To establish a basis for extensive research, a comprehensive survey of the scientific literature on adsorption and adsorbents was begun at the Bureau in 1939, resulting in 1944 in the publication of a 958-page vol-

[1] The technical status of the bone char process has recently been reviewed in a special report entitled *Preliminary survey of bone char revivification and filtration*, by Victor R. Deitz, available from Publications Section, National Bureau of Standards, Washington 25, D. C., at $3 a copy.

ume entitled *Bibliography of solid adsorbents*.[2] The information contained in this book, which covers the years 1900 to 1942, has been kept on a current basis, and a supplementary volume listing the literature for the period from 1943 to 1950 is planned.

By 1946 the project had reached a stage where certain investigations could use the large-scale facilities of a refinery to good advantage. Fortunately, relations between the Bureau and the industry had developed to a point where a number of the sponsors were eager to cooperate. Commercial facilities for handling large quantities of sugar liquors and bone char make possible plant-scale experiments that supplement the laboratory work and permit evaluation of practical applications of fundamental research. Although research that cannot conveniently be undertaken by any one of the cooperating sponsors is still conducted in the laboratories of the Bureau, problems requiring plant facilities for their solution are now studied in a number of individual refineries.

One primary objective in this research has been the attainment of an understanding of the fundamental structure of bone char. This knowledge is essential to a study of the reactions that determine the over-all efficiency of the revivification step. Complete information on the structure of the revivified char delivered to the filter and that of the exhausted char after filtration will make it possible to specify just what the revivification process should accomplish and to suggest logical steps for improvement.

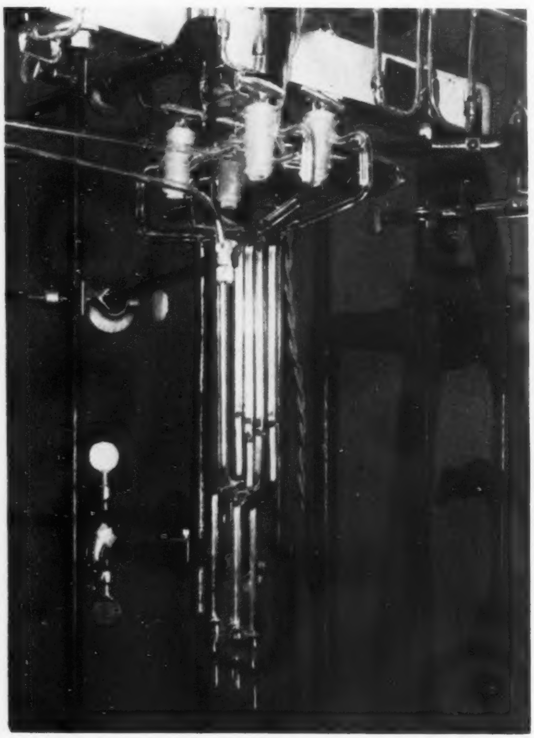
[2] Available from J. M. Brown, Chairman, Bone Char Research Advisory Committee, Revere Sugar Refinery, 333 Medford Street, Charlestown 29, Mass. $12 prepaid.

The structure of bone char has been investigated at the Bureau by means of X-ray diffraction spectra; electron micrographs; density determinations; measurements of surface area available to known gases; chemical analysis; and studies of specific heats, heats of wetting, and heats of combustion. It has been found that the primary structure of the char consists of microscopic crystals of a complex hydroxy-apatite crystal lattice. Superimposed on this is a secondary macrostructure derived from the original cellular composition of bone. The tiny units of the hydroxy-apatite crystals have been slowly deposited during growth in an intricate arrangement. The bone matrix, blood capillaries, and the associated bone-forming cells are also intimately interconnected and thus produce a very porous structure on charring.

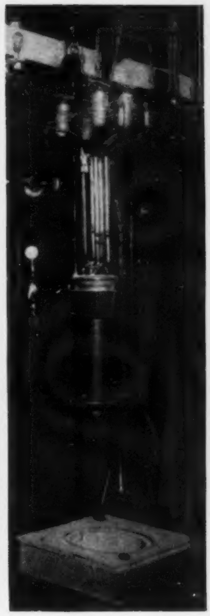
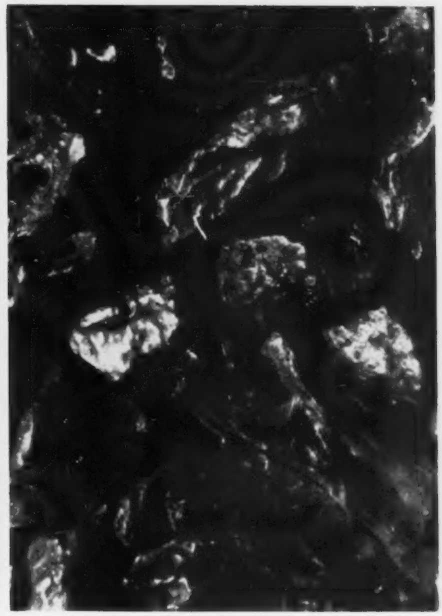
The adsorbing properties of solid adsorbents in general depend, first, upon variations in the extent of available surface and, second, upon effects due to the specific chemical reactivity of the surface. When this project was begun, a new method had just been proposed to determine the surface area of finely divided and porous materials on the basis of the adsorption of nitrogen gas at the temperature of boiling nitrogen (77° K) or of boiling oxygen (90° K). As a result of measurements of a number of samples at the Bureau, it was possible to assign values to the surface areas of bone chars relative to each other with an accuracy of approximately 5 percent. Later studies of the adsorption of nine other gases at various temperatures yielded dependable values for the surface areas that are available to each gas. On the basis of these data, it was first shown that new bone char has a surface area of about 130 square meters per gram or 2¼ square miles per hundred pounds. Service and spent chars were then shown to have smaller areas, which decrease as the ability of the chars to decolorize raw sugar solutions diminishes.

Specific chemical activity at the surface may take the form of reversible or irreversible chemisorption, a catalytic surface oxidation, or an ionic exchange. A catalytic surface oxidation may immediately follow the physical adsorption, yielding products that in some cases may be even more tenaciously held. The evaluation of specific chemical reactivity has been a difficult task; the most promising methods of attack in the case of carbon adsorbents are based on studies of the reaction of the adsorbent with oxygen and the decolorization reactions in raw sugar liquors at various temperatures.

From what has been learned thus far, it is possible to understand the effects of excessive heat treatment in decreasing the adsorptive properties of bone char. In the original bone the crystal unit is extremely small. However, crystal size increases with heating, and the



The surface area of new and spent bone chars is determined at the Bureau by the amounts of certain gases adsorbed by the char. The samples are placed in small glass bulbs (lower center), heated to expel any adsorbed air or gas ("out-gassing"), and then treated at a low temperature with the gas to be adsorbed.

Plant-scale experiments conducted by Bureau personnel in sugar refineries (left) supplement surface area measurements of bone char in NBS laboratories (center) and permit evaluation and practical applications of this fundamental research. Individual granules of the char (greatly magnified, right) have been found to retain the intricate and porous structure of bone even on a submicroscopic level. Laboratory measurements indicate that new bone char has a surface area equivalent to about 2¼ square miles per 100 pounds.

higher the temperature of heating the more rapid is the rate of crystal growth. The effect is aggravated by the gradual accumulation of salts insoluble in the wash waters. These enter into the structure of the crystals, increasing their size, and the subsequent heating develops a more elaborate crystalline aggregate. With the corresponding reduction in porosity of the granules, the available adsorptive surface decreases. Obviously, extreme temperatures in revivification must be avoided if the desirable porosity of the bone char is to be retained. In the present conventional kiln treatment, only the outside shell of char in the retort may be exposed to a dangerously high temperature, but in hundreds of passages through the kiln the probability of exposure of all the char is great.

One of the outstanding characteristic changes in bone char with use is its increase in bulk density. Although new char averages only about 40 pounds per cubic foot, spent char may attain a density of 85 pounds per cubic foot. An investigation in the earlier days of the program showed that the increase in bulk with service was not matched by an appreciable increase in true density as determined from the displacement of a known volume of helium by the char. This demonstrated that shrinkage of bone char did not occur, but that the porous structure within each particle filled up, increasing the weight per unit of bulk volume and decreasing the surface available for adsorption. Some success has been achieved at the Bureau in relating the density of bone char to its ultimate structure. In addition, the accumulated data indicate a rough proportionality between bulk density and several adsorptive properties. This relationship may form the basis of a practical method of testing chars and will, it is believed, provide a rational criterion upon which service char may be safely discarded.

Safety for the Household

The principal hazards to safety in the home, and the means for eliminating or reducing them, are discussed in detail in the new, 200-page edition of *Safety for the household*, now available from the Government Printing Office as National Bureau of Standards Circular C463. Although written mainly for the average present-day household, this booklet provides information that is also of value in the construction and safe operation of schools, hotels, hospitals, stores, warehouses, and industrial plants.

Chapters on gas, building construction, refrigerants, fire prevention, heating equipment, plumbing, fire extinguishers, electrical equipment, and other special items have been prepared by qualified specialists from the various Sections of the Bureau dealing with these particular subjects. The chapter on suggestions for building a home and the discussions of hazards in the use of hand tools and machinery will be found especially helpful.

NBS Circular C463 may be obtained only from the Superintendent of Documents, Washington 25, D. C., at a cost of 75 cents per copy.

Landing-Impact Vibration of Aircraft

The vibration of the airplane structure as a result of the landing impact has become a serious problem with the advent of large transport airplanes. Airplanes of earlier and more rigid types were designed for the landing condition by treating the airplane as a rigid body subjected to a landing-impact force that could be obtained from drop tests of the landing gear. Large transport airplanes designed on this assumption, however, showed an alarming tendency to develop failures in the wing or tail structure that could be ascribed only to transient vibration of the airplane structure excited by the landing impact. To check the validity of present theory concerning such vibrations in the design of large airplanes, an extensive investigation is in progress in the Bureau's engineering mechanics laboratory under the direction of Dr. Walter Ramberg.

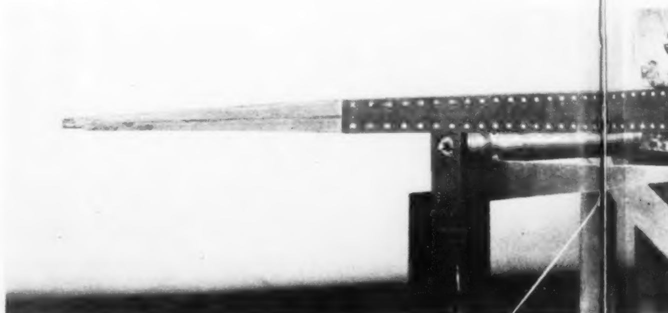
The analysis of the transients during landing impact is complicated by the fact that these transients involve many natural modes of vibration of the airplane, and response in each mode depends on the force-time curve at the point of contact. The force-time curve will vary from one landing to the next of a given airplane. In view of these complications Biot and Bisplinghoff proposed in 1944 [3] an ingenious statistical approach to the landing problem. In this approach the vibration of the structure in a given mode is reduced to that of an equivalent linear oscillator and the maximum amplitude in that mode is estimated from an envelope of "dynamic response factors," which bounds the response to impact force-time curves of any shape that may be expected in the landing. An upper limit to the resultant amplitude is obtained by adding up the maximum amplitudes in the various modes.

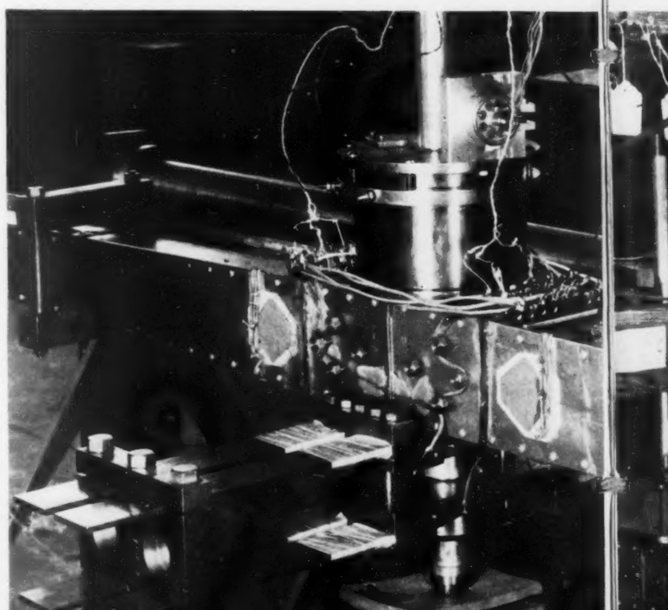
Biot and Bisplinghoff's theory provides a straightforward and rational means for estimating vibration during landing impact. Its application in design seemed advisable provided that the theory could be checked by landing tests under carefully controlled conditions. Unfortunately there is no way of making controlled landings of full-size airplanes. The stresses set up in a full-size airplane will vary from landing to landing depending on the pilot's technique, the attitude of the airplane, the wind direction, and irregularities in the landing strip. Since controlled landings to check the theory are best made in the laboratory on a model of the airplane, the Bureau of Aeronautics requested the National Bureau of Standards to conduct such tests.

[3] M. A. Biot and R. L. Bisplinghoff, Dynamic loads on airplane structures during landing, NACA ARR 4H10 (Oct. 1944).

It was desired that the tests should check, in particular, the adequacy of the following assumptions made by the theory.

1. The maximum amplitudes in the various modes of vibration may be added without regard to phase.
2. The most severe impact force-time curve during the landing approaches, in effect, one of the impact force-time curves used by Biot and Bisplinghoff to derive their envelope of "dynamic response factors."
3. It is sufficient to confine the analysis to the first few modes of vibration.

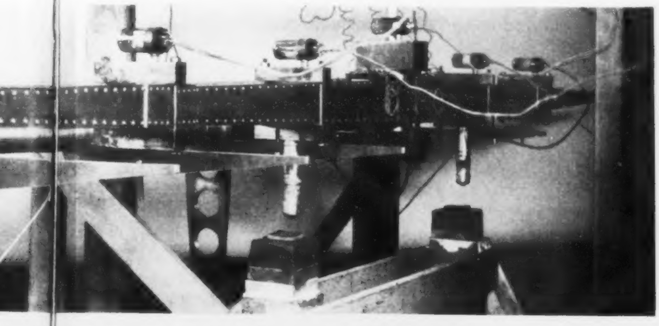


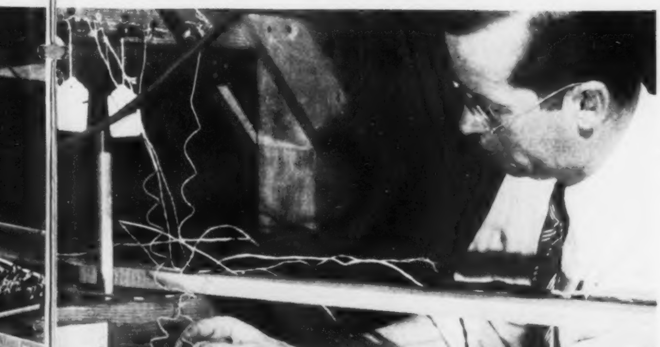


A highly idealized dynamic model of a "4-engine airplane" (top) has been constructed and used at the Bureau for studying the transient vibrations of large airplanes arising from landing impact. The model is released in a strain-free condition by removing the supports simultaneously at an acceleration greater than gravity. The flexibility of the tires is simulated by rubber pads on the synthetic "landing field" upon which the model is dropped (foreground, top and lower left).

4. The force-time curve at the landing gear is independent of the flexibility of the airplane structure.

The work at the Bureau of Standards was started with a study of flexural transients set up in a highly idealized model of an airplane. The model consisted of a tapered box beam fabricated from aluminum alloy sheet and angles. The dimensions of the beams were chosen to give a distribution of mass and of flexural rigidity approximately proportional to that for a well-known transport airplane. Four "engine masses" were mounted symmetrically on the model so as to excite flexural vibrations without torsion when the model was dropped vertically to receive a landing impact below the center of gravity. The model contained an alighting gear below the fuselage with means for adjusting the time history of the impact force acting on the wings. Measurements were made of impact force, spring force, and damping force transmitted by the alighting gear; bending moments at two stations; and accelerations at the fuselage.





Release in a "strain-free" condition is important to prevent vibration of the wing during free fall, caused by the sudden release of gravity forces that produce initial sag of the wing under its dead weight. The model was initially held in a practically strain-free condition by supporting it at several points and adjusting the position of the supports until the strains caused by the dead weight of the wing were negligible. The model was released in its strain-free condition by removing all supports simultaneously from under the wing at an acceleration greater than 1g. The flexibility of the tires was simulated by adding rubber to the synthetic "landing field," upon which the model was dropped. The landing-impact force, and the damping and spring force transmitted by the alighting gear, were measured with pickups utilizing strain-sensitive wire; bending moments in the wing were measured with wire strain gages; and the acceleration at the fuselage was measured with one of the vacuum-tube acceleration pickups [4] developed by Dr. Ramberg.

The investigation of landing impact at the National Bureau of Standards is continuing along both experimental and theoretical lines. Unsymmetrical two-point landings have been made with the same model equipped with alighting gears underneath the two inboard "engines." The recorded transients in these unsymmetrical landings are being compared with theory. Tests are planned to study torsional transients set up in a model with "engine masses" set forward relative to the center line of the wing. Additional tests are proposed for studying the transients set up during the alighting of a model wing airplane on water. Eventually it may be necessary to extend the work to a study of transients excited by the horizontal components of landing force that "spin up" the landing wheels. Service landings indicate that these may cause serious vibration of the airplane.

Along theoretical lines, methods are being investigated by the Bureau to shorten the laborious work of computing natural modes of vibration of the airplane structure and to compute the response to hard impacts that may excite vibrations in many natural modes. It is reasonable to expect that a rational method of design of large airplanes against landing impact will result eventually from the combined attack on the problem by

[4] Walter Ramberg, Vacuum-tube acceleration pickup, J. Research NBS 37, 391 (1946) RP1754.

The model was built to give a distribution of mass and flexural rigidity approximately proportional to that of an actual airplane. Note the engine mass, fuselage, and alighting gear for symmetrical landing tests (lower left) and the two-point alighting gear for unsymmetrical tests (top). Various devices are used to measure forces and strains developed in the landing tests. Among these are the vacuum-tube acceleration pickups developed at the Bureau (lower right).

analysis, model tests, and service landings of full-size airplanes.

The observed bending moments and accelerations were compared with values computed from Biot and Bisplinghoff's theory. In addition a more exact analysis, taking account of phase differences, was made for one of the actual impact force-time curves. The comparison showed that the values obtained from Biot and Bisplinghoff's theory were 15 to 140 percent greater than the measured values, and that the error caused by neglecting phase differences was negligible.

It was concluded from the tests that the Biot and Bisplinghoff theory would give a fair estimate, generally on the safe side, for the transient vibration in an airplane subjected to symmetrical landing impact leading to flexural vibration of the wing.

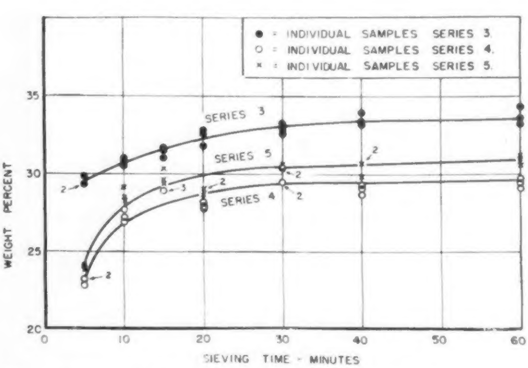
Measurements on actual landings of large transport airplanes have failed to substantiate this conclusion. In certain cases the measured accelerations were much larger than those computed from the theory. It has been suggested that this might be due to inadequacy of the envelope of response factors, and that it might be due to interaction between the landing gear and the flexible airplane.

The first explanation was studied by including the effect of unsymmetrical landings in the impact force-time curves or "forcing functions" that lead to the envelope curve. It can be shown that unsymmetrical two-point landings will excite unsymmetrical modes of the wing with a forcing function that can be approximated by a full sine wave. The response to such a forcing function was found to be about 50 percent greater than that given by Biot and Bisplinghoff's envelope curve for a time of impact approximately equal to the period of the mode considered. This provides at least one possible explanation for the observed discrepancy between measured and computed accelerations during actual landings.

The second explanation was studied by determining the effect of bending of the wing in its fundamental mode on the forcing function applied by the idealized landing gear used in the one point landing tests of the model wing. The wing of the airplane was replaced by a cantilever beam with a tip mass. The effect of flexibility was increased by increasing the proportion of mass carried at the tip. In each case the force was determined when this model made contact with the ground at a given velocity of descent. The experimental solution for the effect of flexibility was obtained by measuring the impact force for drop tests with masses at the wing tips and with all mass at the fuselage. Both tests and analysis showed that the flexibility reduced the maximum force at the landing gear. The reduction was slight, less than 10 percent in nearly all cases. It was concluded that the observed discrepancy between calculated and measured accelerations during service landings should not be attributed to wing flexibility.

Particle-Size Distribution in Powder Metallurgy

Advances in the science of powder metallurgy—the art of making objects by pressing and heating metal powders—have long been hindered by the difficulty of obtaining reproducible results in large-scale manufacture. This is due principally to present methods and techniques that introduce numerous variables, as yet not completely understood or controllable. One phase of the current program for standardization of test methods and techniques in this field has consisted of an extensive investigation, in the Bureau's metallurgical laboratories, of the conditions contributing to the poor reproducibility of sieve analyses of metal powders. Such analyses of particle-size distribution are of major importance in powder metallurgy.



Sieve tests of sponge iron made with 100-gram samples from the same "sample supply" indicate the effects of different treatments of the powder: Series 3, dried; series 4, humidified; series 5, samples from series 4 dried and resieved.

Investigations at the Bureau [5] have revealed that atmospheric humidity has a marked effect on the results obtained by sieve analyses of metal powders and that controlled atmospheric conditions during sieve testing of metal powders may therefore be necessary when close control of particle size is desired. Increase in humidity tends to increase the weight of the fractions retained on the sieves and decrease the weight of the pan fraction. Differences of as much as 10 percent between the weight of fractions of powdered iron sieved under high and low humidities have been observed.

In sieve tests of sponge iron, electrolytic iron, electrolytic copper, and nickel, for the purpose of accumulating supplies of sieved fractions of these powders for other studies, it was found that reproducible results could be obtained only when certain variables were controlled. Significant differences in sieve analysis often were obtained when samples of the sieve powder were sieved at different times with the same sieves. Furthermore, different sets of certified sieves used for the same

[5] For further technical details of this work see, Sieve tests of metal powders, by R. E. Pollard, J. Research NBS **39**, 487 (1947) RP1843.

TABLE 1. *Sieve tests of sponge iron showing variations due to replacement of sieves*

Average of 3 tests on 100-gram samples sieved 30 minutes with certified sieves

Sieve No.	With original No. 325 sieve		With new No. 325 sieve (NBS No. 8887)		Difference from original (3) minus (1)	With new No. 325 sieve (NBS No. 8888)		Difference from original (6) minus (1)	Difference between new sieves (6) minus (3)
	Mean	Deviation from mean	Mean	Deviation from mean		Mean	Deviation from mean		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
PERCENTAGE, BY WEIGHT, OF SPONGE IRON RETAINED WITH SIEVE SET 1									
80	Trace		Trace			Trace			
100	do		do			do			
140	7.3	+0.1 to 0.2	7.0	+0.1 to 0.2	−0.3	6.9	+0.1 to 0	−0.4	
200	22.6	± .1	22.4	+ .2 to .4	−.2	22.6	± .1	0	
325	31.2	+ .4 to .5	38.2	± .1	+7.0	41.0	+ .4 to .2	+9.8	+2.8
Pan	38.4	+ .2 to .1	32.0	+ .2 to .1	−6.4	28.9	± .3	−9.5	−3.1
PERCENTAGE, BY WEIGHT, OF SPONGE IRON RETAINED WITH SIEVE SET 2									
80	Trace		Trace			Trace			
100	do		do			do			
140	4.4	±0.6	5.2	+0.1 to 0	+0.8	5.1	0	+0.7	
200	24.4	±.6	23.5	+ .1 to 0.3	−.9	23.3	±0.1	−1.1	
325	33.0	±.2	38.6	+ .3 to .2	+5.6	40.8	+ .1 to 0	+7.8	+2.2
Pan	37.9	±.2	32.2	± .1	−4.7	30.2	± .1	−7.7	−2.2

powder gave variations of considerable magnitude. A contributing factor, in addition to atmospheric humidity, was a cumulative sampling error that resulted from repeated riffle cutting of limited powder supplies.

The effects of these variables were demonstrated by tests on sponge iron. This powder was made from reduced mill scale and consisted of irregular platelike particles. Many of the larger particles were made up of several such plates held together by the oxide of the metal. The sampling procedure included the use of a riffle-type sample splitter to reduce the entire supply of metal powder (50 to 100 lb) to "sample supplies" that could be stored in one to five 1-pint Mason jars (3 to 15 lb).

Tests of the effect of high humidity on the sieving characteristics of sponge iron illustrated the difficulty of reproducing analyses of metal powders. The set of certified U. S. Standard sieves used in these tests (Sieve set 3) included No. 100, 140, 200, 230, and 325. One-hundred gram samples taken from the same freshly riffle cut sample supply were sieved for periods of 5, 10, 15, 20, 30, 40, and 60 minutes after the following treatments of the powder:

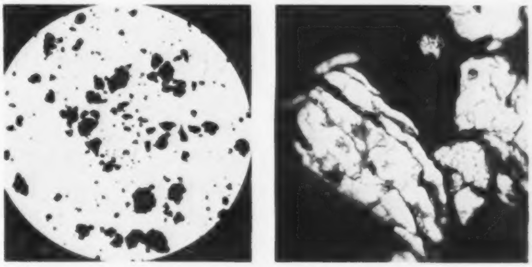
Series 3.—For each time period three samples were oven dried for 1 hour at 110° C prior to sieving.

Series 4.—For each time period three samples were exposed for 64 to 72 hours to a humid atmosphere in a closed vessel (desiccator) over water, with wicks dipped into the water to increase the evaporating surface.

Series 5.—After sieving, the humidified samples of Series 4 were mixed, dried for 5 hours at 110° C, and resieved.

For the humidified samples, Series 4, the amounts of material retained on each sieve were consistently lower than those of the dried material, Series 3. For example, differences in the case of the pan fractions ranged from 3.5 to 6.5 percent of the original weight of the sample. Part of this difference (approximately 25%) was recovered when the humidified samples were dried and resieved, as shown by the values obtained for Series 5. Values for the individual samples of Series 3 lay close to the curve of the plotted results, but the values for Series 4 and 5 were more scattered. Similar but smaller differences were obtained for the other sieve fractions.

Two additional series of tests were made using the same sieves and the same procedure as in Series 3, but with samples taken from different sample supplies. The differences between each succeeding series, in the order in which they were riffle-cut, amounted to about 1 percent of the original weight of the sample. It is believed that these differences were due chiefly to the loss of fines as dust during riffle cutting.

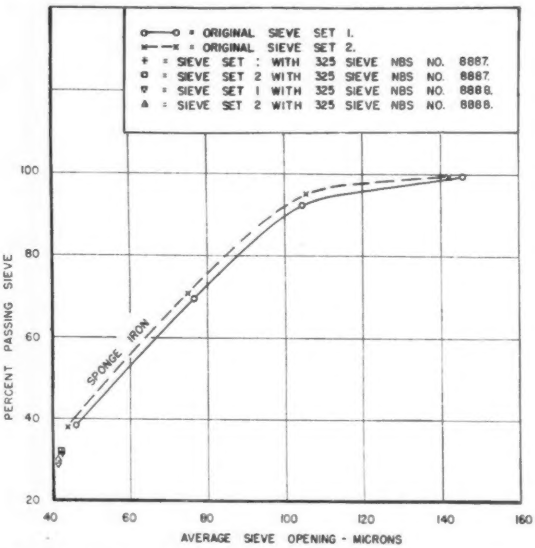


Micrographs of sponge iron powder made from reduced mill scale show that the powder consists of irregular platelike particles (left, X25), and that some of the larger particles are made up of smaller plates cemented together (right, X250) with the oxide.

Variations of considerable magnitude also were noted when powders were sieved with different sets of certified sieves. The results obtained with sponge iron when replacements of the No. 325 sieve were made in two sieve sets are given in table 1. The tests were made under approximately the same sieving conditions, and all samples were taken from the same sample supply.

The fractions retained by the sieves that were not replaced (all sieves larger than No. 325) agreed closely. The new No. 325 sieves retained 7.0 and 9.8 percent more material respectively with Sieve set 1; and with Sieve set 2, 5.6 and 7.8 percent. The amounts retained by the two new sieves differed by 2.8 percent when used with Sieve set 1 and 2.2 percent with Sieve set 2.

In connection with these differences, it is interesting to compare the average openings of the several sieves as measured during the certification tests. These measurements are given in table 2. From a plot of the values of table 1 against the measurements of the average openings, it is evident that the differences between



Cumulative weight distribution curves of sponge iron based on average openings of the certified sieves show better agreement between different sieves than comparisons based on the nominal openings.

TABLE 2. *Average opening of sieves as measured in certification tests*

Sieve Number	NBS Certification Number	Average opening, microns [a]	
		Between warp wires	Between short wires
ORIGINAL SIEVE SET 1			
80	8805	186	174
100	8806	143	148
140	8807	107	102
200	8808	78	75
325	8809	46	46
ORIGINAL SIEVE SET 2			
80	8889	185	174
100	8890	144	140
140	8891	104	107
200	8892	77	73
325	8893	43	45
NEW NO. 325 SIEVES			
325	8887	41	43
325	8888	41	42

[a] Measurements were made by the Bureau's Metrology Division with an accuracy sufficient to determine whether the openings were within the limits permitted by specification. The errors are probably not in excess of about 1 micron.

sieves are considerably less than they would be if the comparison were made on the basis of the nominal opening. The agreement probably would be even closer if the variations in sieve openings could be taken into consideration. Due to manufacturing limitations, the dimension tolerances of wire cloth permitted by specifications are necessarily rather wide, particularly for fine sieves. These variations are not fully reflected by the measurements of the average opening.

Further investigations of possible methods of eliminating, controlling, or evaluating the effects of these and other variables encountered in sieve analyses of metal powders are needed, and studies toward this end are under way at the Bureau.

Symposium on Wind Tunnel Optics

The first symposium on Wind Tunnel Optics—a new field concerned with wind tunnel instrumentation, especially for supersonic velocities—was sponsored recently by the National Bureau of Standards under the technical direction of Dr. I. C. Gardner of the Optical Instruments Section and C. H. Hahner of the Glass Section. Representatives of several Government agencies interested in this work attended the meeting and took part in an informal program that brought out interesting problems connected with this branch of optical engineering.

For many years wind-tunnel measurements were limited chiefly to pressures and forces produced by air moving about objects. With the relatively recent advent of high speeds, reaching and even greatly exceeding that of sound, it has become possible to observe the flow field by optical methods. This not only makes the wind tunnel a more versatile research tool, but in particular, makes possible the observation of important phenomena associated with compressibility, which occurs at speeds now regularly achieved by projectiles, rockets, and by some of the jet propelled planes that

have been developed or are now on the drawing boards.

The flow of air around a solid object is accompanied by changes in pressure that give rise to variations in the index of refraction of the air. These variations may be made visible by interferometric or schlieren apparatus, the design, construction, and use of which are embraced by the recently coined term "wind-tunnel optics". This is really a branch of optical engineering in which well-established principles of optics are applied as tools in an entirely distinct art. As distinguished from other branches of engineering, the equipment required is of a different order of size from interferometric and schlieren apparatus constructed for the longer established practices. Interesting demands are thus placed on the glass maker.

The construction of large glass disks of optical quality became a neglected art several decades ago when reflecting telescopes supplanted refractors. Now, however, disks 36 inches in diameter are often required, and even larger constructions have been contemplated. Bureau staff members from the glass laboratory and the optical instruments laboratory discussed problems connected with the production of large windows and disks of interferometer or schlieren quality, both by casting and by other methods. Of particular importance is the elimination of optical heterogeneities by reduction of temperature gradients in annealing. Techniques for the measurement of strain and for testing the planeness and parallelism of surfaces were also described.

Although the optical principles back of wind-tunnel optics are well-established, their applications to this relatively new field call for specialized techniques and interpretations. Schlieren methods, interpretation of results of interferometer measurements, and production of fringes with heterochromatic light were among the topics of this nature brought up for discussion.

Representatives of the Army, Navy, and Johns Hopkins Applied Physics Laboratory took part in the program, in addition to those from the Bureau of Standards. Although this symposium was limited to Government agencies, future symposia are planned in which other interested groups will participate.

Calibration of 500-Gallon Capacity Measure

Calibration of a 500-gallon trailer-type standard measure, submitted by officials of the State of Illinois for certification, has been accomplished by weighing on the Bureau's vehicle scale, the only weighing device with sufficient capacity and accuracy at present available for such a test. The standard was tested, adjusted, and "sealed" by the Bureau.

It is important that State weights and measures organizations be equipped with accurate large-capacity measures in order to make correct tests of the various types of tanks and discharge meters used to measure the quantities of fuel oil, gasoline, and other liquid commodities transported by highway vehicles. Obviously, the 5-gallon measure is inadequate when it is considered that many tanks have capacities of hundreds of gallons and that discharge meters may have a discharge rate of more than 100 gallons a minute.

To achieve the required accuracy of calibration, with corresponding precision, all weighings were made by the substitution method. In this method the weight indications of the weighbeam are not used. The load is applied, the weighbeam equilibrated, and its position of equilibrium (rest point) determined by recording the turning points of a pointer with reference to an index scale at the tip of the weighbeam. The load is then removed and known weights added to obtain the same readings of the index scale. The weights necessary to restore the position of equilibrium are therefore equal to the load being weighed.

The repeated weighings of the gross load of approximately 7,000 pounds showed a maximum deviation of weight values of only 0.12 pound; this is less than two parts in one hundred thousand. The final results of the calibration are considered accurate to 0.25 pound, which is equivalent to plus or minus 7 cubic inches on the total capacity of the measure.

NBS Scientists

Several appointments in the National Applied Mathematics Laboratories have recently been announced. **Dr. Churchill Eisenhart,** well known for his work in mathematical statistics and its applications in the biological sciences, industry, and engineering, heads the Statistical Engineering Laboratory, which plans and advises in the mathematical and statistical phases of scientific research and testing. Dr. Eisenhart was elected vice-president of the Institute of Mathematical Statistics at its annual meeting in December. **Dr. Arnold N. Lowan,** who has been in charge of the Mathematical Tables Project conducted by the Bureau in New York, has been named Chief of the Computation Laboratory. This laboratory, which is at present underwritten by the Office of Naval Research, provides a computation service and is continuing the work of the Mathematical Tables Project in the preparation of tables used in statistical and mathematical analysis. **Albert S. Cahn** has been designated executive officer of the Institute of Numerical Analysis, which has been located on the campus of the University of California at Los Angeles through a cooperative agreement between the University and the Bureau.

Dr. Harry D. Huskey, authority on large-scale automatic digital computing machinery, has been appointed Chief of the Machine Development Laboratory to succeed **Dr. E. W. Cannon,** who will devote full time as Assistant Chief of the National Applied Mathematics Laboratories. During the past year Dr. Huskey was engaged in research at the British National Physical Laboratories on the design of a pilot model of the "ACE", the British automatic computing machine. He has also served as consultant on the ENIAC project at the Moore School of Electrical Engineering, University of Pennsylvania.

NBS Publications

Periodicals [6]

Journal of Research of the National Bureau of Standards, volume **40**, number 3, March 1948. (RP1865 to RP1870 inclusive.)

Technical News Bulletin, volume **32**, number 3, March 1948. 10 cents.

CRPL–D43. Basic Radio Propagation Predictions for June 1948. Three months in advance. Issued March 1948. 10 cents.

Nonperiodical

Research Papers [6, 7]

RP1858. Lenses of extremely wide angle for airplane mapping. Irvine C. Gardner and Francis E. Washer. 10 cents.

RP1859. Effect of annealing and other heat treatment on the pH response of the glass electrode. Donald Hubbard and Gerald F. Rynders. 10 cents.

RP1860. Infrared radiation from a Bunsen flame. Earle K. Plyler. 10 cents.

RP1861. Perforated cover plates for steel columns; compressive properties of plates having ovaloid, elliptical, and "square" perforations. Ambrose H. Stang and Bernard S. Jaffe. 10 cents.

RP1862. Behavior of certain sugars and sugar alcohols in the presence of tetraborates—correlation of optical rotation and compound formation. Horace S. Isbell, Joseph F. Brewster, Nancy B. Holt, and Harriet L. Frush. 15 cents.

RP1863. Effect of inhibitors on the corrosion of zinc in dry-cell electrolytes. Clarence K. Morehouse, Walter J. Hamer, and George W. Vinal. 10 cents.

RP1864. Thermodynamic functions for molecular oxygen in the ideal gas state. Harold W. Woolley. 10 cents.

Applied Mathematics Series

AMS1. Tables of the Bessel functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$, $K_1(x)$. $0 \leq x \leq 1$. 35 cents.

Building Materials and Structures Reports

BMS110. Paints for exterior masonry walls. Clara Sentel. 15 cents.

Commercial Standards

CS144–47. Formed metal porcelain enameled sanitary ware. 10 cents.

CS146–47. Gowns for hospital patients. 10 cents.

Simplified Practice Recommendations

R148–47. Glass containers for cottage cheese and sour cream. (Capacities, weights, dimensions, and finish). (Supersedes R148–33.)

Handbooks
(Correction Sheets)

Correction sheets, changes adopted by the Thirty-Third National Conference on Weights and Measures, 1947. (To supplement H29, Specifications, tolerances, and regulations for commercial weighing and measuring devices.) Available upon request from the National Bureau of Standards, Washington 25, D. C.

Letter Circulars [8]

LC890. List of commercial standards, revised to January 1, 1948. (Supersedes LC878.)

LC871 (Supplement No. 1). Bibliography of some recent research in the field of high polymers. (Continuation to December 31, 1947.)

Articles by Bureau Staff Members in Outside Publications [9]

Science and the national welfare. E. U. Condon. Science (1515 Massachusetts Avenue NW., Washington 5, D. C.) **107,** 2 (1948).

Developments in radio sky-wave propagation research and applications during the war. J. H. Dellinger and Newbern Smith. Proc. Inst. Radio Eng. (1 East Seventy-ninth Street, New York 21, N. Y.), **36,** 258 (1948).

El tecnico y el publico frente a los modernos procesos de acabado. Carlos Camposortega. Camara Textil de Mexico (Mexico, D. F.) **1,** No. 5, 12 (December 31, 1947).

Silicate cements—How to select and use them. George C. Paffenbarger. North-West Dentistry (Minnesota State Dental Association, 434 LaSalle Building, Minneapolis, Minn.) **27,** No. 1, 29 (January 1948).

Prism spectrometry from 24 to 37 microns. Earle K. Plyler. J. Chem. Physics (57 East Fifty-fifth Street, New York 22, N. Y.) **15,** 885 (1947).

The enthalpy, entropy, and specific heat of liquid *p*-xylene from 0° to 300° C.; the heat of fusion. D. C. Ginnings and R. J. Corruccini. J. Am. Chem. Soc. (1155 Sixteenth Street NW., Washington 6, D. C.) **69,** 2291 (1947).

The thermodynamic properties and molecular structure of cyclohexane, methylcyclohexane, ethylcyclohexane, and the seven dimethylcyclohexanes. C. W. Beckett, K. S. Pitzer, and R. Spitzer. J. Am. Chem. Soc., **69,** 2488 (1947).

Thermodynamics and molecular structure of cyclopentane. J. E. Kilpatrick, K. S. Pitzer, and R. Spitzer. J. Am. Chem. Soc. **69,** 2068 (1947).

Developments and improvements in methods of stress-strain testing of rubber. J. W. Schade and F. L. Roth. Symposium on rubber testing, Tech. Pub. No. 74, American Society for Testing Materials (1916 Race Street, Philadelphia 2, Pa.), 109 pages (1947).

Development and standardization of tests for evaluating processibility of rubber. Rolla H. Taylor, J. H. Fielding, and M. Mooney. Symposium on rubber testing, Tech. Pub. No. 74, American Society for Testing Materials (1947).

Standardization of testing and inspection in government synthetic rubber plants. Ludwig Meuser, Robert D. Stiehler, and R. W. Hackett. Symposium on rubber testing, Tech. Pub. No. 74, American Society for Testing Materials (1947).

Testing and grading of wild and plantation rubbers. Norman Bekkedahl. Symposium on rubber testing, Tech. Pub. No. 74, American Society for Testing Materials (1947).

Sunspots and very-high-frequency radio transmission. K. A. Norton. QST (38 La Salle Road, West Hartford 7, Conn.) **31,** No. 12, 13 (December 1947).

The ionosphere as a measure of solar activity. M. Lindeman Phillips. Terrestrial Magnetism and Atmospheric Electricity (Johns Hopkins Press, Baltimore 18, Md.) **52,** No. 3, 321 (Sept. 1947).

Variations in sporadic-E ionization observed at Washington, D. C. M. Lindeman Phillips. Trans. Am. Geophysical Union (1530 P Street NW., Washington 5, D. C.) **28,** No. 1, 71 (1947).

The comparisons of predictions of atmospheric radio noise with observed noise levels. E. L. Shultz. Trans. Am. Geophysical Union **28,** No. 6, 854 (1947).

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[6] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, $4.50 (foreign $5.50); Technical News Bulletin, $1.00 (foreign $1.35); Basic Radio Propagation Predictions, $1.00 (foreign $1.25). Single copy prices of publications are indicated in the lists.

[7] Reprints from February Journal of Research.

[8] Available upon request from the National Bureau of Standards, Washington 25, D. C. Letter Circulars are prepared to answer specific inquiries addressed to the Bureau, and are sent only upon request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of Letter Circulars or send copies automatically as issued.

[9] These publications are not available from the Government. Requests should be sent direct to the publishers.

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